Final Report

Mechanical Midstory Reduction Treatment: An alternative to prescribed fire.
Joint Fire Science Program Project 99-1-3-06

Bob Rummer, Ken Outcalt, Dale Brockway, D. Craig Rudolph

Executive Summary

This project investigated the effects of using mechanical midstory reduction treatments on vegetative and herptofaunal communities. In addition, it developed basic productivity information for several types of machines. Mastication, or grinding, of the midstory is becoming a common prescription for reducing forest fuels as a preparation for prescribed fire or as a substitute for burning. However, it is a capital-intensive operation that will generally require follow-up treatment with fire, herbicide, or re-mastication. Machine costs, and thus treatment cost per acre, is directly related to horsepower. Heavy fuel loading and terrain are the key factors affecting productivity. Therefore it is important to match the type of prime mover to the terrain requirements and the horsepower rating to the fuel loading of planned mastication treatments.

The mastication treatment accomplished the goal of reducing the midstory layer by selectively removing hardwoods, which had increased in abundance and size during the period of fire exclusion. Thus, the chipping treatment can be used for rapid readjustment of stand structure and reduction of ladder fuels and thereby wildfire hazard. The chipping treatments also reduced woody cover in the understory layer while increasing overall species diversity. Although grass cover increased some on treated areas the dominant species remained very similar to pre-treatment conditions. A continued program of regular prescribed burning will be required to keep the midstory fuels from reforming and to readjust the understory composition to a more herbaceous dominated layer.

Introduction

Fire control and exclusion in fire-evolved forest types such as loblolly pine (*pinus taeda*), longleaf pine (*pinus palustris*), ponderosa pine (*pinus ponderosa*) and pond pine (*pinus serotina*) have allowed the development of midstory components of shade tolerant species. In natural stands, this midstory structure would be absent or significantly reduced. The development of midstory results in increased fuel loading, significant alterations of wildlife habitat, and alterations of nutrient cycling. These changes are generally detrimental to ecosystem health and sustainability. Land managers need a tool or process that will manipulate the midstory component of forestlands in the United States where natural fire cycles have been disrupted.

Fire, or a fire surrogate, is an essential tool for forest resource management in fire-evolved ecosystems. There are vast acreages of with resulting midstory encroachment. Forests in Condition Class 2 and 3 are characterized (Schmidt et al. 2002) as moderate and high departure from natural fire regimes, respectively. In order to address this significant forest health and fuels management issue, midstory reduction (MSR) is often prescribed as the initial step of a management plan to reintroduce fire or as an ongoing replacement for fire where constraints, such as smoke management or urban interface, preclude regular burning. MSR treatments may include marketing of small-diameter products, cut-and-leave, or cut-and-reduce. Generally, marketing and cut-and-leave are not viable options and mechanical reduction of midstory is the prescribed method.

Unfortunately, managers have limited information about the effectiveness, costs, and limitations of widespread mechanical reduction treatments. Is mechanical reduction of midstory an effective surrogate for prescribed fire? Does prescribed fire through mechanically-processed material behave like fire through natural fuels? What are the impacts of the various mechanical treatments to the residual stands and other ecological functions? How do factors of terrain, soils, stand structure or type affect the selection and application of mechanical treatments? A comprehensive understanding of these basic questions is needed to support the development of landscape-level land use and planning processes. Therefore, this study was established as a wide-ranging investigation of the costs, impacts, and ecological outcomes of MSR treatments in southern pine stands.

The project consisted of an interdisciplinary evaluation of MSR treatments in two forest types (southern pine and mixed pine-hardwood) that represent a large portion of the southern coastal plain and Piedmont physiographic regions. One study site was located on the Ft. Benning Military Reservation near Columbus, GA, the second site was located on the Winn District of the Kisatchie National Forest near Winnfield, LA.

Primary Objectives:

1. Quantify the production rates and costs of several alternative types of mechanical midstory reduction operations.
2. Assess the effects of the midstory reduction treatments on reduced material, residual stand damage and soil disturbance.
3. Evaluate the effect of these operations on herptofaunal populations (abundance and diversity)
4. Ascertain changes in fuel quality and quantity resulting from application of mechanical treatments.
5. Quantify the biological decay rate of residual fuels, including changes in particle size class distribution and total dry phytomass
6. Determine the optimum time interval after mechanical treatment at which to safely re-introduce prescribed fire into the system
7. Monitor changes in understory and overstory plant communities related to biological production, species diversity and regrowth of fuels.

Methodology

The Ft. Benning site was established with 20, approximately 3-acre plots on two treatment areas in March 2000. Five 15-m vegetation sampling transects and 5 overstory sampling subplots were defined in each plot. Based on topographic similarities, the plots were aggregated and then randomly assigned to a prescribed fire treatment. Vegetation surveys were conducted pre-treatment, post-treatment, and post-burn. Most of the plot area (~60 ac) was masticated with a rubber-tired Magnum 500 using a flail hammer cutterhead by the end of October 2000. Approximately 15 acres of soft soils and steep slopes required treatment with a tracked Delta 953C with a fixed-tooth cutterhead which was completed in July 2001. Gross productivity was measured with shift-level records and area surveys. Fuel loading was measured post-treatment on 1m^2 subplots.

On the Kisatchie National Forest site, three pairs of 20-acre blocks were identified in May 2000. In each pair, one block was masticated with a rubber-tired ROWMEC T-7 while the other block was treated with a flextracked ROWMEC GT-18. Gross productivity was measured with shift-level times and total area treated. Ten 15-m permanent vegetation sampling transects were located in each block, five transects were placed in adjacent untreated control areas. Vegetation surveys were conducted prior to treatment, after mastication, and after burning that occurred in 2001. Three wildlife trapline arrays were placed in each block and trapline counts were conducted for two seasons.

Results by Objective

1) Quantify production rates and costs for alternative MSR treatments.

Comparative machine specifications are listed in Table 1. The options tested in this study covered the range of ground pressure, horsepower and cutter types that are associated with direct-mount mastication equipment. The Kisatchie National Forest site was a direct comparison of a wheeled machine with a low-ground pressure tracked machine using identical cutterheads. The Ft. Benning treatments allowed production assessments of the highest horsepower machine options—tracked and wheeled.

Table 1. Comparison of machine specifications

Specification	GT-18	T-7	Delta 450	Magnum 500
Carrier type	flex track	wheeled	steel track	wheeled
Horsepower	190 hp	150 hp	450 hp	450 hp
Cutter width (in)	94”	94”	96”	96”
Overall width (in)	108”	109”	114”	120”
Tooth style	stirrup flail	stirrup flail	fixed	hammer flail
Total weight (lbs)	19,000#	23,500#	50,000#	47,300#
Ground pressure (psi)	2.0 psi	6.6 psi	7.4 psi	10.9 psi
Approx. purchase price	$180,000	$200,000	$385,000	$385,000

On the Kisatchie sites both machines operated at high utilization, completing 60 acres each in 9 scheduled days. Productivity was not significantly different between the T7 and GT-18 averaging 1.04 and 1.07 acres/productive hour respectively. Using standard machine rate costs, per acre treatment costs were $83/acre and $76/acre respectively. These costs do not include overhead or profit and risk.

At Ft. Benning, the Magnum 500 experienced significant delays—logging only 36 percent utilization. Delays included mechanical breakdowns, problems caused by metal debris on the site, and several instances of being stuck in soft soils. Slopes of the treated areas averaged 15%. When operating, the Magnum was productive with an average 0.96 ac/PMH. Using the observed utilization rate would result in a treatment at $258/acre, assuming better utilization would reduce the cost to $169/acre. The remaining area (15 acres) consisting of short slopes up to 35% and soft flats was masticated with the Delta 953C. At 1 ac/PMH, the Delta treatment was about $171/acre on the flat ground, and up to $650/acre on the steep slopes.

2) *Assess effects of MSR on reduced material, residual stand damage and soil disturbance.*

Mastication effects on reduced material were documented under Objective 4 below. Previous evaluations of MSR treatments found residual stand damage similar to levels experienced on conventional thinning treatments with wheeled feller-bunchers (~15% of residual stems with some damage). At both the Kisatchie and Ft. Benning sites the residual stand density of about 250 trees per hectare permitted mastication with minimal residual stand damage.

3) *Evaluate the effect of MSR treatments on herptofaunal populations*

The Louisiana pine snake (*Pituophis ruthveni*), a candidate species for listing under the U. S. Endangered Species Act, and other species of amphibians and reptiles are often sensitive to vegetation structure. Fire regimes are an important determinant of vegetation structure in many ecosystems. Pine communities in the southeastern U. S. have been impacted by widespread fire suppression activities for many decades. Consequently, extensive habitat changes have occurred that impact amphibian and reptile communities. Mechanical methods are often used to begin the restoration of suppressed sites and as a partial surrogate for frequent fire in pine ecosystems in the southeastern U. S. In the Louisiana portion of this project, mechanical methods reduced woody vegetation in the understory and midstory, and when followed by prescribed fire resulted in an increase in herbaceous vegetation in the understory (Outcalt and Brockway 2001). Surveys for amphibians and reptiles, following mechanical treatment, demonstrated the presence of amphibian and reptile species and abundances characteristic of fire-maintained pine habitats in the region. The presence of the Louisiana pine snake, in particular, demonstrates the ability of the treated sites to support this species that depends on fire-maintained communities. Overall, there appeared to be no obvious differences between mechanical treatments beyond what would be expected due to local site differences. Continued application of prescribed fire will be required to maintain and improve the habitat of the treatment sites for those species, including the Louisiana pine snake, that are dependent on habitat characteristics that result from frequent fire.

4) *Ascertain changes in fuel quality and quantity resulting from application*

Detailed measurements of fuel outcomes were taken at the Ft. Benning site from 25, 1m^2 plots. All masticated material in each plot frame was collected, dried and sorted by fuel size class. The average total treated fuel loading was 19.8 bone-dry tons/acre (44 Mg/ha). If these fuels were spread evenly over the site the resulting layer would be about ½" deep. The understory and midstory vegetation was reduced to material in the following fuel classes:

Table 2. Fuel classification of masticated material from Ft. Benning.

Fuel classification (minor dimension)	% of total dry biomass
< ¼"	26.7
¼" – 1"	37.8
1" – 3"	23.0
> 3"	12.5

5) *Quantify the biological decay rate*

The mastication treatments at Ft. Benning were not implemented with a single machine as planned. In addition, the timing between plots was confounded by a delay of nearly 9 months to complete the treatments between the two machines. The original planned decomposition study was not able to be implemented with these complications since the samples could not be started at the same point in time. Estimates can be made, however, based on the fuel sampling data and appropriate decay rates from the literature. Sanchez, Carter and Klepac (2003) monitored soil chemistry and physical property changes under masticated and incorporated treatments. While they did not measure decay rates of surface materials, their results found that mastication combined with tilling increased soil C and N, reduced bulk density and cone index. Butler and Van Lear (1984) used cross-sectional methods to estimate decomposition rates of loblolly pine logging slash and concluded that decay rates were greatest in larger pieces and in pieces with ground contact. Tiarks et al (1999) established a long-term woody debris decomposition study as part of the LTSP program, although their data is only reported for the first 6 months. Their initial results support the finding that larger material decays more quickly than smaller material. Using the decay rate functions estimated by Butler and Van Lear and the fuel classifications described above, the half-life of the masticated material would be about 10 years (Fig. 1).

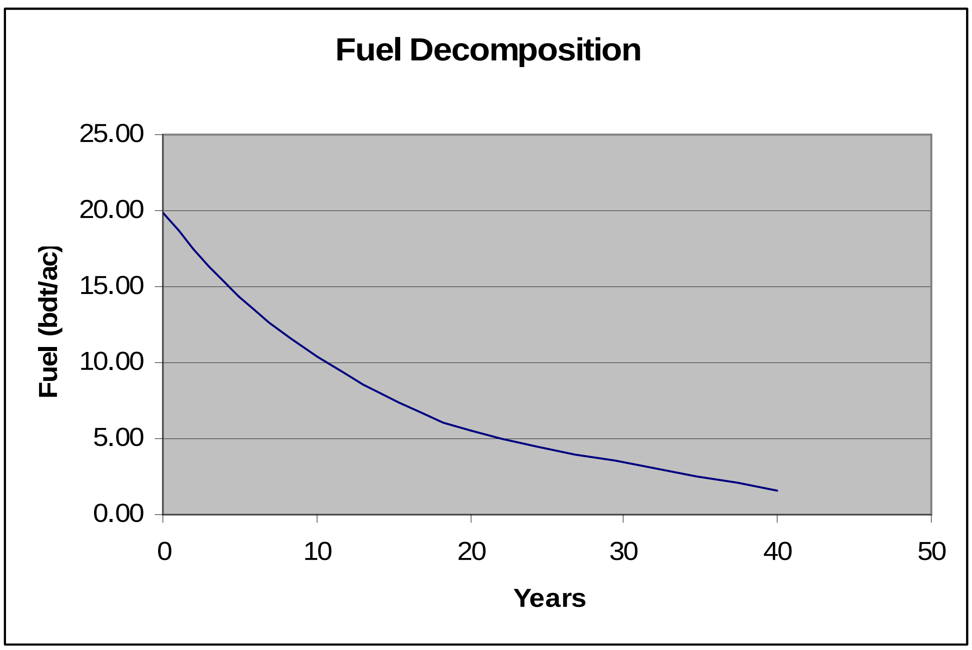

Figure 1. Estimated decomposition of masticated material at Ft. Benning.

6) *Determine the optimum time interval after treatment to re-introduce fire*

We noted that the cutting teeth on the centripetal hammers of both machines are quite effective in reducing woody plants in the midstory and altering the structure of the forest environment. The aftermath of mechanical treatment saw a residual stand mostly composed of larger-diameter trees, fewer in number than before. Thus, tree density declined while average tree diameter increased. Overall, stand basal area declined by 40 percent. Woody plants began to sprout back almost immediately, especially on wetter bottomland areas. Thus, introducing prescribed fire to these areas as early as possible was key to deriving any lasting ecological benefit from the mechanical reduction. Where fire was delayed for more than one growing season, a very thick woody understory of shrubs, vines and hardwood tree sprouts quickly developed. Therefore mechanical treatment alone should not be seen as viable treatment by itself. Rather, mechanical treatment should be seen as a technique that eclipses an important ecological threshold related to stand structure and composition. Once a forest is mechanically treated, it is crucial that prescribed fire be quickly introduced to sustain in the long term the short-term gains thus achieved.

7) Monitor changes in plant communities

On the Kisatchie site, the objective of the study was to compare the effectiveness of thinning using mastication followed by prescribed burning to burning only for restoring stand structure and composition. In April 2000, diameters were measured for tree stems greater than 5cm, while cover and frequency of other plants were recorded in six mixed stands of longleaf (*Pinus palustris*), shortleaf (*P. echinata*), and loblolly pine (*P. taeda*). Half of each stand was treated with a masticator in May 2000 and the stands were burned in spring of 2001. Before treatment, pines dominated the tree layer of both chip and burn and burn only areas while hardwoods dominated the middle and understory layers. The mechanical treatment reduced the density of hardwoods in the midstory by 33% and the understory by 64%. The understory was dominated by the same species before the treatment and at the end of the first growing season. Cover of grasses increased equally on both thin and unthinned areas over the first growing season while there was no change in cover of forbs or vines. Woody understory cover, however, increased by 13% on non-thinned areas and declined by an equal amount on treated areas. Following the burns, grasses and forbs increased equally on both chipped and unchipped sites, while woody understory remained significantly lower on chipped areas.

Data from the Ft. Benning site found that mechanical treatment caused declines in overstory and midstory tree density (1220 to 258/ha) and basal area (31 to 18 m^2/ha) and a corresponding increase in mean DBH (13 to 29 cm), with the largest reductions in *Pinus taeda*, *Liquidambar styraciflua*, *Quercus nigra* and *Q. hemisphaerica*. Despite declines in tree species richness (9 to 4) and diversity (1.32 to 0.84), increased evenness (0.72 to 0.85) indicated improved distribution equity among residuals. Understory tree cover declined 17% overall and cover increases of 9% were observed for shrubs & vines (*Smilax* and *Vitis* expansion) and grasses (*Chasmanthium* appearance). Forb cover increases were very modest, averaging < 4%. Understory plant diversity remained generally unchanged following treatment, with increases noted for species richness corresponding to declines in evenness. While not producing large initial growth increases in herbaceous plants, prescribed fire is needed following mechanical treatment to stimulate grasses and forbs and curtail redevelopment of the woody plant midstory.

The mastication treatment clearly produces an immediate alteration in stand structure, however vegetative responses to the adjustment continue over a longer period of time.

Deliverables:

The proposal stated, “The project will produce refereed journal articles, technical releases, field demonstrations and a reference notebook for field-level application.” Outputs from this project are listed below. Refereed journal articles remain to be completed.

1. **Refereed articles, proceedings papers**
    a. Rummer. (in preparation) Production and cost of mastication treatments for fuel reduction. Journal of Forest Engineering
    b. Rudolph, D.C.; Burgdorf, S.; Schaefer, R.; Connor, R.; Maxey, R. (in press) Status of the Louisiana pine snake. Southeastern Naturalist.
    c. Brockway, Outcalt. (in preparation)

Rummer, B. 2004. Technology for treating fuels and small-diameter material. In: One Forest Under Two Flags. Proceedings of the Joint 2004 Annual Meeting and Convention. Society of American Foresters.

2. Technical Releases, Posters, Presentations

Outcalt, K.; Brockway, D. 2001. Response of a southern pine community to re-adjustment of stand structure [**Abstract, Poster**]. In: Abstracts Book, 86th Annual Ecological Society of America Meeting. Washington, DC: ESA:326.

Rummer, B.; Brockway, D.; Outcalt, D.; Rudolph, D. Craig. 2000. Mechanical midstory reduction treatment: an alternative to prescribed fire [**Abstract**]. At: JFSP Principal Investigator Workshop. Reno, NV.

Rummer, B. 2001. Mechanical treatments for fuels management. At: 11th Biennial Silviculture Research Conference. Knoxville, TN (**poster**)

Rummer, B. 2001. Mechanical mid-story reduction for fuel treatment. At: 18th Annual Inland Empire Forest Engineering Conference. University of Idaho: Moscow, ID

Rummer, B. 2002. Mechanical midstory reduction treatment: an alternative to prescribed fire. At: JFSP Principal Investigator Workshop. San Antonio, TX. *Presentation was awarded Best Oral presentation and subsequently offered to the JFSP Stakeholder Advisory Group. Boise, ID.*

Rummer, B.; Outcalt, K.; Brockway, D. 2002. Mechanical midstory reduction treatments for forest fuel management [**Abstract**]. In: New Century New Opportunities. Proceedings of the 55th Annual Meeting, Southern Weed Science Society. Atlanta, GA: 76.

Rummer, B. 2002. Alternative operations to treat biomass in fuel reduction treatments. At: Fire in Southern Forests. Sarasota, FL.

Brockway, D.; Outcalt, K.; Estes, B.; Rummer, R. 2004. Restoring longleaf pine forest ecosystems: plant community response to mechanical midstory reduction and prescribed fire on sandhills at Ft. Benning, GA. At: Coastal Plain Chapter of the Society for Ecological Restoration.

Outcalt, K.W., and D.G. Brockway. 2004. Restoration of pine communities on the Kisatchie National Forest with mechanical chipping and fire. At: 2004 Meeting of the Coastal Plain Chapter of the Society for Ecological Restoration: p.16.
Rudolph, D. C., R. N. Carrie, and J. Hamrick. Habitat use by the Louisiana pine snake at Fort Polk, LA. Strategic Environmental Research and Development Program, Technical Symposium & Workshop on Threatened, Endangered, and At-Risk Species on DoD and Adjacent Lands. Baltimore, MD, 7-9 June 2005.

Rudolph, D. C., R. N. Carrie, and J. Hamrick. Louisiana pine snake population, status, and trends. JRTC and Fort Polk Sustainability Workshop for Red-cockaded Woodpecker and Louisiana Pine Snake Populations, Fort Polk Louisiana. Fort Polk, LA, 28-30 2005.

Rummer, B. 2003. Fact Sheet #2. Mastication treatments and costs. Fuels planning science synthesis and integration. http://www.fs.fed.us/fire/tech_transfer/synthesis/economic_utilization_team/fact_sheet.htm [Date accessed: June 16, 2005]

Additionally, elements of the productivity and equipment studies of mastication have been incorporated into at least 10 other presentations on the topics of forest fuel treatment, small diameter harvesting, biomass by Rummer.

A new video, "Introduction to Mechanized Equipment for Fuels Treatment and Land Management" is being produced by USDA for the US Forest Service, San Dimas Technology Development Center. Rummer served on the development team and incorporated mastication treatment information.

3. Demonstrations and Workshops

Field demonstrations were held at each treatment site. Prior announcements were circulated to US Forest Service and Fish and Wildlife personnel based on regional staff listings. Demonstrations included:

9/30/2000	Magnum 500	Ft. Benning, GA
5/30/2001	Franklin 4995	Desoto National Forest, MS
7/17/2001	Delta 953	Ft. Benning, GA
10/31/2001	5 machines	Auburn, AL

Fuels Reduction Workshop. October 30 – November 1, 2001. Auburn, AL. Based on the field studies of equipment, Rummer developed a workshop format with Jim Sherar, R-8 to provide training on implementation of mastication treatments. The workshop included sections on equipment performance and cost, contracting options, NEPA, and case studies from southern Districts. There was also a field tour to the Ft. Benning research site with demonstration of equipment. Based on the JFSP support, the 44 attendees included employees of FWS as well as the Forest Service.

Based on the 2001 Auburn Workshop, San Dimas Technology Development Center proposed a new Regional Mechanical Fuels Treatment Workshop. It extended the program to a week and included a hands-on hypothetical fuels treatment project planning exercise. The course was offered once in 2002 and twice each year in 2003, 2004, and 2005. The summary of mastication equipment performance, cost and outcomes constitutes approximately 2.5 hours of class instruction (agenda in Appendix).

4. Decision and Reference Tools

My FTP (Fuel Treatment Planner). This decision support tool is a spreadsheet-based cost calculator to estimate fuel treatment costs given stand conditions, product markets, and treatment options. One component of this integrated tool is a mastication module that estimates MSR treatment costs based on productivity and cost data assembled with the

JFSP project. http://www.fs.fed.us/pnw/publications/firetools.shtml [Date accessed: June 21, 2005]

Mastication Webpage. www.srs.fs.usda.gov/forestops/biomass.html This link on our Unit website provides reference information including presentations on equipment options, costing, case studies, and site impacts. In addition, copies of presentations from the vegetation and wildlife components of the JFSP study are available.

References

Barber, B.L.; Van Lear, D.H. 1984. Weight loss and nutrient dynamics in decomposing woody loblolly pine logging slash. Soil Sci Soc Am J. 48:906-910.

Sanchez, F.G.; Carter, E.A.; Klepac, J. 2003. Enhancing the soil organic matter pool through biomass incorporation. Biomass and Bioenergy 24:337-349.

Schmidt, K.M.; Menakis, J.P.; Hardy, C.C.; [and others]. 2002. Development of coarse-scale spatial data for wildland fire and fuel management. Gen. Tech. Rep., RMRS-GTR-87. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Tiarks, A.; Klepzig, K.; Sanchez, F.; Lih, M.; Powell, J.; Buford, M. 1999. In: Haywood, J.D., ed. Proceedings of the 10th Biennial Southern Silviculture Research Conference. Gen Tech Rep. SRS-30. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 238-42.